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The Coexistence and Interference Evaluation of Bluetooth with IEEE 802.11 Networks

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Abstract

This paper discerns key ideas and themes of Bluetooth and WiFi system used in mobile communication. In this article the coexistence of WiFi and Bluetooth are shown with simulink model in MATLAB and it also shows that the interference issues of these two individual systems. Almost 75% of the devices in the mobile computing world are equipped with either one of these or both. These technologies use the Radio Frequency (RF) for communication. The Bluetooth operates in 2.4GHz Industrial Science Medical (ISM) band. Unfortunately IEEE 802.11 also operates in the same 2.4GHz ISM band. There are different versions of IEEE 802.11 like 802.11a, 802.11b, 802.11g, and 802.11n to name a few. Some of them operate in a different frequency range. This paper reflects the coexistence and interference of both technology and shows the existence of each technology with same band.

***Keywords*: Bluetooth, WiFi, Industrial Science Medical, Coexistence, Interference**

1. INTRODUCTION

Bluetooth device can send both voice and data packet through a radio channel with a data rate of 1Mbps. Bluetooth is a short range Personal Area Network (PAN). Its operating range is normally 10meters. Transmitting power of a Bluetooth transmit power is very low. It's just about 1mw. Bluetooth uses Gaussian Frequency Shift Keying (GFSK) modulation technique. Bluetooth also uses Frequency Hopping Spread Spectrum technique to reduce interference from other devices operating in the same frequency spectrum. Interference in Bluetooth system can be recovered or sometimes avoided using various coexistence techniques [1]. This technique provides a good resolution for mutual interference between co located IEEE 802.11 networks. But when it comes to a co-located Bluetooth and IEEE 802.11 network they just don't communicate each other [2]. So there is no way they will identify each other. There is a definite chance of collision when they use the same channel at a particular time. A Bluetooth device may haphazardly begin transmitting packets while an IEEE 802.11 device is sending a frame. This may result in interference, which forces the IEEE 802.11 station to retransmit the frame when it realizes that the destination station is not going to send back an acknowledgment. This lack of coordination is the basis for interference between Bluetooth and 802.11.

Wi-Fi SPECIFICATIONS

Wireless communication is one of the fastest-growing technologies [3]. The demand for connecting devices without the use of cables is increasing everywhere. Wireless LANs can be found on college campuses, in office building, and in many public areas. We concentrate on two promising wireless technologies for LANs: IEEE 802.11 wireless LANS, sometimes called wireless Ethernet, and Bluetooth, a technology for small wireless LANs [4]. Although both protocols need several layers to operate, we concentrate mostly on the physical and data link layers.

IEEE 802.11

IEEE has defined the specifications for wireless LAN, called IEEE 802.11, which covers the physical and data link layers. Standards defines two kinds of services: the basic service set (BSS) and the extend service set (ESS).

Basic Service Set

IEEE 802.11 defines the basic service set (BSS) as the building block of a wireless LAN. A basic service set is made of stationary or mobile wireless stations and an optional central base station known as the access point (AP)[2-7]. The BSS without an AP is stand-alone network and cannot send data to the others BSSs. It is called Adhoc architecture. In this architecture, station can form a network without the need of an AP is sometimes referred to as an infrastructure network.

Extended Service Set

An extended service set (ESS) is made up of two or more BSSs with APs. In this case, the BSSs are connected through a distribution system, which is usually a wired LAN. The distribution system connects the APs in the BSSs. IEEE 802.11 does not restrict the distribution system; it can be any IEEE LAN such as Ethernet .The extended service set uses two types of stations : Mobile and stationary. The mobile stations are normal stations inside a BSS. The stationary stations are AP stations that are part of a wired LAN. When BSS are connected, the stations within reach of one another can communicate without the use of an AP. However, communication between two stations in two different BSSs usually occurs via two APs. The idea is similar to communication in a cellular network if we consider each BSS to be cell and each AP to be a base station.

Physical Layer of WiFi

The IEEE 802.11 wireless LAN working group was founded in 1987 to begin standardization of spread spectrum WLANs for use in the ISM band .The evaluation of IEEE 802.11 Wireless LAN standards, which also include infrared communication. The figure shows how both frequency hopping and direct sequence approaches were used in the original IEEE 802.11 standard.

Table 1: The addresses of different layer of Wi-Fi

IEEE Specification	Technique	Spectrum Band	Modulation Scheme	Data Rate (Mbps)
802.11	FHSS	2.4GHz	FSK	1 and 2
	DSSS	2.4GHz	PSK	1 and 2
		Infrared	PPM	1 and 2
802.11a	OFDM	5.725 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.4GHz	PSK	5.5 and 11
802.11g	OFDM	2.4GHz	Different	22 and 64

IEEE 802.11 FHSS

It uses the frequency hopping spread spectrum (FHSS) method and the frequency is 2.4GHz ISM band. The band is divided into 79 sub-bands of 1 MHz [8]. A pseudorandom number generator selects the hopping sequence. The modulation technique in this specification is either two levels FSK or four levels FSK with 1 or 2 bit/baud, which results in a data rate of 1 or 2 Mbps.

IEEE 802.11 DSSS

Direct sequence spread spectrum (DSSS) method uses the 2.4 GHz ISM band. The modulation technique in this specification is PSK at 1 Mbaud/s. The system allows 1 or 2 bits/baud (BPSK or QPSK), which results in a data rate of 1 or 2 Mbps.

IEEE 802.11 Infrared

It uses infrared light in the range of 800 to 950 nm. The modulation technique is called pulse position modulation (PPM). For a 1-Mbps data rate, a 4 bit sequence is first mapped into a 16 bit sequence in which only one bit is set 1 and the rest are set to 0 [2] [8]. For a 2 Mbps data rate, a 2 bit sequence is first mapped into a 4 bit sequence in which only one bit is set to 1 and rest are set to 0. The mapped sequences are then converted to optical signal, the presence of light specifies1 and the absence of light specifies 0.

IEEE 802.11a OFDM

IEEE 802.11a OFDM describes the orthogonal frequency division multiplexing method for signal generation in a 5 GHZ ISM band. OFDM is similar to FDM with one major difference where the subbands are used by one source at a given time. Source contained with one another at the data link layer for access. The band is divided into 52 subbands, with 48 subbands for sending groups of bits at a time and 4 sub-bands for control information [5]. The scheme is similar to ADSL with dividing the band into subbands diminishes the effects of interference. If the subbands are used randomly, security can also be increased. OFDM uses PSK and QAM for modulation. The common data rates are 18 Mbps (PSK) and 54 Mbps (QAM).

2. BLUETOOTH SPECIFICATION

Bluetooth device can send both voice and data packet through a radio channel with a data rate of 1Mbps. Bluetooth is a short range Personal area network (PAN). Its operating range is normally 10 meters. Transmitting power of a Bluetooth transmitter is very low [6]. It’s just 1mw. Bluetooth uses Gaussian Frequency Shift Keying (GFSK) modulation technique. Bluetooth also uses Frequency Hopping Spread Spectrum technique to reduce interference from other devices operating in the same frequency spectrum. Interference in Bluetooth system can be recovered or sometimes avoided using various coexistence techniques.

Bluetooth Simulation Model

Bluetooth is a short-range radio link technology that operates in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band. The model modulates the signal using Gaussian frequency shift keying (GFSK) over a radio channel with maximum capacity of 1 Mbps. The demo uses frequency hopping over a 79 MHz frequency range to avoid interference with other devices transmitting in the band. In this scheme, the sender divides transmission time into 625-microsecond slots, and uses a new hop frequency for each slot. Although the data rate is only 1 Mbps, a much larger bandwidth of 79 MHz is required to simulate the frequency hopping effects.

3. SIMULATION RESULTS

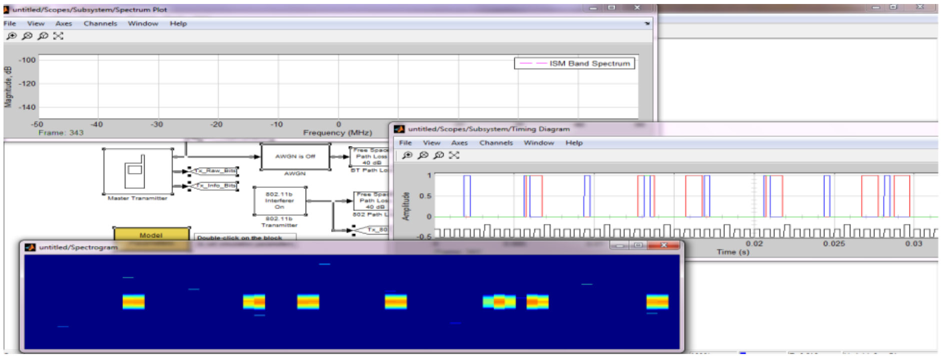

Fig. 1: Output from Simulink to show the coexistence of Wi-Fi with Bluetooth

The raw bit error rate displays the inconsistencies between the bits in the transmitted signal and the received signal. Frame error rate refers to the ratio of frame failure to the total number of frames. Frame failure, caused by noise and interference, is determined if the HEC fails to match the header info or if less than 57 bits are correct in the access code. If the frame fails, this is captured by a zero-valued Frame OK signal, which is used in the FER calculation as well as to exclude bad frames from the residual BER calculation. The Scopes icon opens a display of the spectrum of the transmitted Bluetooth signal (narrowband) with IEEE 802.11b interference (Fig. 1 – Fig. 4).

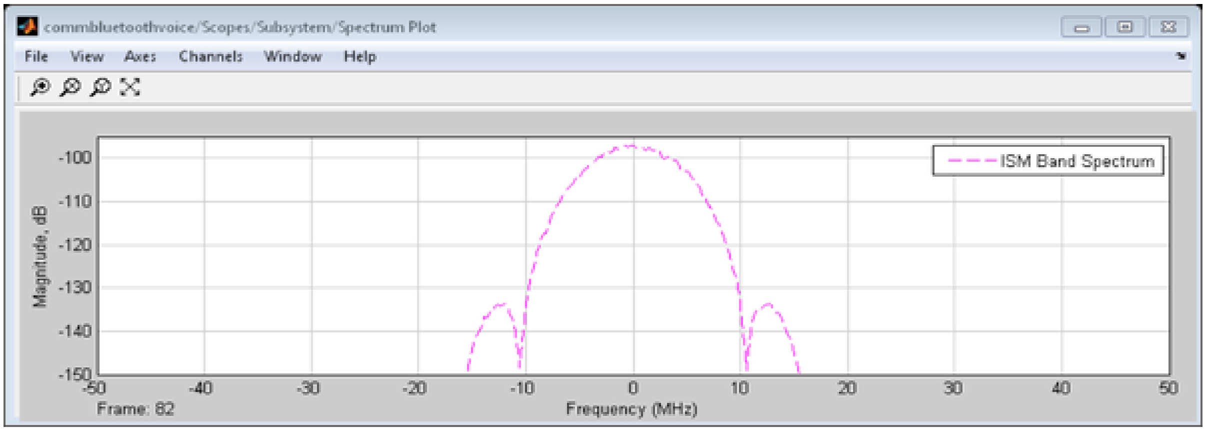

Fig. 2: The timing diagram for the Bluetooth and interferer slots is also available.

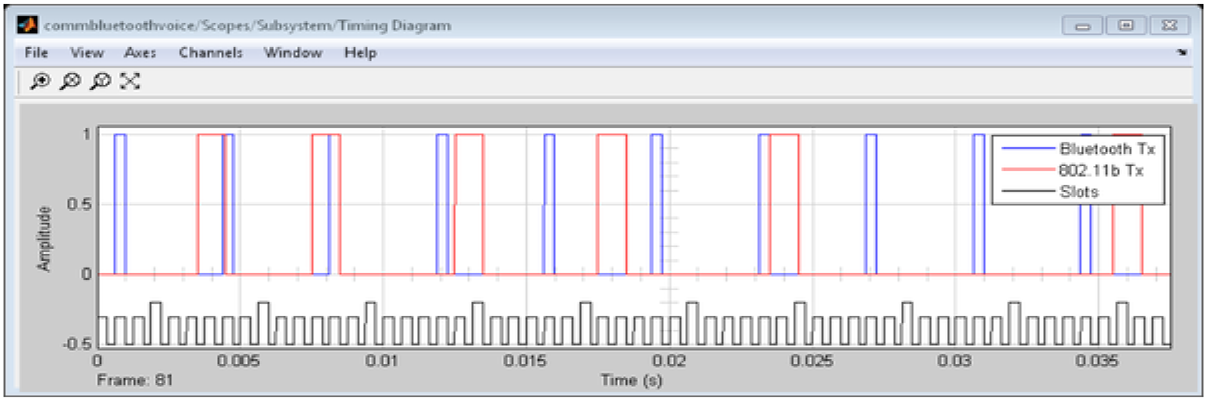

Fig. 3: A dynamic plot of packet frequency versus time is shown by the Spectrogram plot.

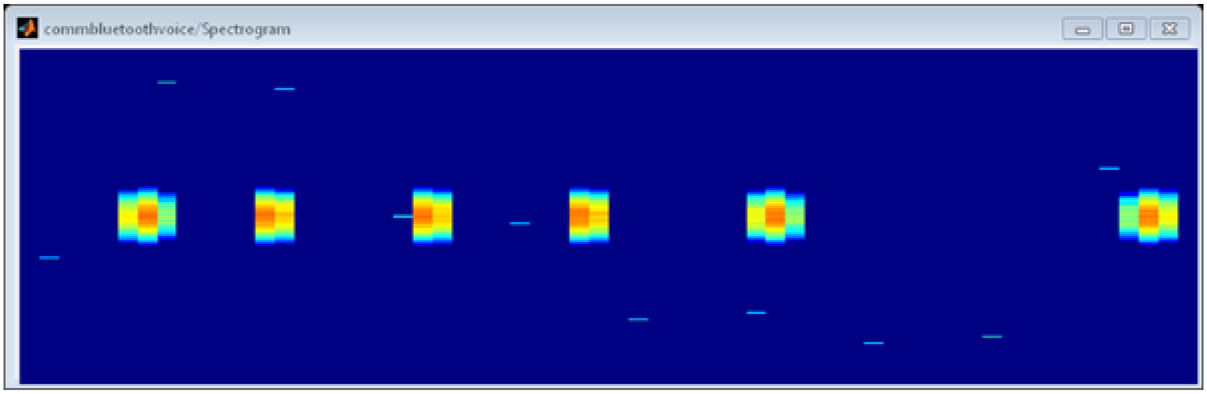

Fig. 4: The thin lines are the Bluetooth transmissions, while the larger, more colorful blocks are the interferer slots. Most of the time, due to frequency hopping, there is not much overlap of these slots. In a few cases, the signals collide, as the Spectrogram plot clearly shows.

4. CONCLUSION

Coexistence, and ultimately simultaneous operation, between 802.11 and Bluetooth is a highly desirable goal. Both technologies are expected to grow rapidly over the next few years, offering new levels of portability and convenience, and many critical usage models require collocation and simultaneous operation of both standards in the same device. The Bluetooth and the IEEE 802.11 both are working in an unlicensed band so that the existence of the both technology are shown in Matlab simulation. Their existence is shown that the both technologies are coexistence with each other.

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